Preparing your intensive care unit to respond in crisis: Considerations for critical care clinicians

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Objective: **In recent years, healthcare disaster planning has grown from its early place as an occasional consideration within the manuals of emergency medical services and emergency department managers to a rapidly growing field, which considers continuity of function, surge capability, and process changes across the spectrum of healthcare delivery. A detailed examination of critical care disaster planning was undertaken in 2007 by the Task Force for Mass Critical Care of the American College of Chest Physicians Critical Care Collaborative Initiative. We summarize the Task Force recommendations and available updated information to answer a fundamental question for critical care disaster planners: What is a prepared intensive care unit and how do I ensure my unit's readiness?**

Data Sources: **Database searches and review of relevant published literature.**

Data Synthesis: **Preparedness is essential for successful response, but because intensive care units face many competing priorities, without defining "preparedness for what," the task can seem overwhelming. Intensive care unit disaster planners should, therefore, along with the entire hospital, participate in a hospital or regionwide planning process to 1) identify critical care response vulnerabilities; and 2) clarify the hazards for which their community is most at risk. The process should inform a comprehensive written preparedness plan targeting the most worrisome scenarios and including specific guidance on 1) optimal use of space, equipment, and staffing for delivery of critical care to significantly increased patient volumes; 2) allocation of resources for provision of essential critical care services under conditions of absolute scarcity; 3) intensive care unit evacuation; and 4) redundant internal communication systems and means for timely data collection.**

Conclusion: **Critical care disaster planners have a complex, challenging task. Experienced planners will agree that no disaster response is perfect, but careful planning will enable the prepared intensive care unit to effectively expand its capability in times of crisis. (Crit Care Med 2011; 39:000–000)**

KEY WORDS: disaster; ICU; preparedness

In recent years, healthcare disaster planning and preparedness have grown from their early place as occasional considerations within the manuals of emergency medical services and emergency department managers to a rapidly expanding field, which considers continuity of function, surge capability, and process changes across the spectrum of healthcare delivery. Preparations for delivery of surge critical care, crucial for adequate response to numerous disasters (1, 2), have expanded in both the breadth of operational considerations and depth of tactics. A detailed examination of critical care disaster planning was undertaken in 2007 by the Task Force for Mass Critical Care of the American College of Chest Physicians Critical Care Collaborative Initiative (hereafter, Mass Critical Care Task Force) (3–7). Although much progress has been made since the publication of that work in 2008, many intensive care units (ICUs), challenged by competing priorities, remain underprepared. We summarize the essential guidance of the Task Force as well as available updated information (8, 9) to answer a fundamental question for critical care disaster planners: What is a prepared ICU and how do I ensure my unit's readiness?

A Prepared ICU

Preparedness is essential for successful disaster response. Because ICUs face many competing priorities, without defining "preparedness for what," the task can seem overwhelming. In recent years, planning guidance has targeted Department of Homeland Security National Planning Scenarios (10), many of which assume scores of fatalities and thousands of hospitalizations. Although targeting preparedness for such catastrophic events is a worthwhile goal, true preparedness for most National Planning Scenarios is an enormous undertaking. We therefore argue that initial planning may reasonably be focused toward smaller events of higher probability.

Ideally, disaster planners would have validated metrics that could drive a turnkey approach to ICU preparedness. Although such tools are lacking, much can still be done as the field awaits the development of quality metrics and validated processes. The first step is to identify the type and scope of events that a given ICU is most likely to face. To this end, ICU planners should, along with the entire hospital, complete a hazard vulnerability analysis (HVA) (11). A variety of tools are available to guide HVAs, including the often-used Kaiser model (12). We do not advocate isolated ICU HVAs; instead, we argue that critical care providers should participate in a hospital or regionwide process that 1) clarifies the hazards for which their community is most at risk; and 2) incorporates subanalysis to iden-

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tify critical care response vulnerabilities that may not be apparent to non-ICU staff. The HVA should inform a comprehensive written preparedness plan targeting the most likely scenarios. Critical care personnel should ensure that plans include specific guidance on 1) optimal use of space, equipment, and staffing for delivery of essential critical care to significantly increased patient volumes; 2) allocation of the resources needed to deliver essential critical care in conditions of absolute scarcity; 3) evacuation of ICUs; 4) redundant internal communication systems; and 5) means for timely data collection.

We urge that ICU planning not be done in isolation, but rather, like the HVA, occur in concert with analogous efforts for individual practitioners, hospitals, and regions. Although here we focus on the preparedness planning for a single ICU or multiple ICUs in one hospital, the broader response framework must be carefully considered. At the individual level, staff must 1) have a personal disaster plan for themselves and loved ones; and 2) help to develop, understand, and ultimately agree with the local expectations of clinician duties during a disaster response. At the hospital level, planning must address continuity of operations at all levels of care with specific attention to what services may be safely curtailed to allow for the care of significantly more acutely ill patients than baseline. ICU leadership must both support hospitalwide preparedness objectives and engage with a hospitalwide disaster committee that can facilitate collaboration with other ICUs through a regional emergency management infrastructure.

It cannot be overemphasized that the most effective planning is carried out through an iterative, multidisciplinary, collaborative process that engages clinical staff, facilities engineers, materials management personnel, administrators, community members, and other relevant stakeholders. Furthermore, these stakeholders should have significant current experience working in the areas they are asked to address. They should be engaged in plan development, not simply plan review, and they should be empowered to enact change in their respective areas, if needed. It is within this broader context that the ICU disaster planner should pursue the response elements discussed subsequently.

Provision of Essential Critical Care With Surges in Volume

Space. Surge critical care planners must first identify and prioritize appropriate clinical space to support the specialized needs of the critically ill. On average, 68% of the nearly 94,000 U.S. nonfederal critical care beds are occupied (13). Historically, larger hospitals have tended to have much higher ICU occupancy rates (14). Small events with a handful of critically ill patients may tax responding ICUs, but most can find sufficient patient care space. For events resulting in scores of critically ill or injured victims, all but the largest of regions or metropolitan areas' critical care capabilities will be overwhelmed.

In an era of rising healthcare costs, maintaining significant numbers of appropriately equipped ICU beds solely for disaster use is likely to be an unpopular use of healthcare dollars (9). Thus, during moderate and large-scale events, critical care will be provided outside of traditional ICUs, at least initially. For modest surges, postanesthesia care units, emergency department critical care areas, and monitored beds in outpatient procedure areas can provide some additional space. The surge capability of these spaces is likely to be limited, and filling these areas with critically ill inpatients is likely to impair a hospital's ability to maintain routine patient flow because critically ill and injured victims often require days or weeks of care. Thus, use of these spaces should be considered only a temporizing strategy. Importantly, although general inpatient, noncritical care services may be delivered in nonhospital settings (15), the need for supplemental oxygen, monitoring equipment, and diagnostic facilities makes critical care delivery in most nonhealthcare buildings of opportunity risky and unfeasible. Because complex critically ill patients are likely to have worse outcomes if cared for in buildings of opportunity rather than hospital settings, such space should space should first be used to care for those with medical needs not serious enough to warrant inpatient admission but not appropriate for care at that person's usual residence (e.g., home or long-term care facility).

If ICUs are full, critically ill patients should be managed in spaces that most closely match the monitoring, medical gas, and suction capabilities of ICUs. Once these spaces are full, critically ill patients may be moved to the next functional level of hospital ward, and if the lowest acuity wards are full, the lowest acuity patients may be considered for transfer to care in buildings of opportunity. Critically ill patients should only be cared for in nonhospital settings, however, if the risk to patients or staff from using available hospital space is so high (e.g., risk for structural collapse after an earthquake) that it exceeds the risk of delivering critical care in nontraditional settings. Use of some nontraditional healthcare settings for critical care delivery (e.g., veterinary hospitals, deployable medical facilities) may be less risky if they are deliberately built for that purpose.

Equipment. Many types of disasters can cause overwhelming respiratory failure, and, without surge planning, numerous patients may die without the benefit of mechanical ventilatory support. Although manual ventilation may be a short-term solution, its use on an ongoing basis will be limited by excess oxygen use, inconsistent minute ventilation, and, for contagious diseases, risk of transmitting infection to care providers. Strategies for rapid expansion of ventilator inventories include use of rental supplies, repurposing of anesthesia machines and noninvasive ventilation devices, and accessing ventilator stockpiles. In the United States, the majority of the full-feature mechanical ventilator supply is required to support even small surges in demand (16). Although rental supplies may be helpful, a recent regional drill revealed that only 16 rental ventilators were available to support up to 3500 surge critical care beds (17).

The U.S. Centers for Disease and Prevention's Strategic National Stockpile (18) currently maintains thousands of ventilators for deployment during disasters. To assess potential Strategic National Stockpile ventilator availability, planners should contact their state Strategic National Stockpile official for the current ventilator allocation policy for their region. Some hospitals may consider developing individual ventilator stockpiles, but stockpiling full-feature ventilators may be unwise as a result of the cost and significant training required for their use. Instead, the stockpiling of sophisticated portable ventilators has been recommended (19). To be useful, such ventilators should provide a certain minimum set of features (19, 20) (Table 1) and disaster plans should include mechanisms for both pre-event

Table 1. Concise disaster planning checklist for intensive care unit clinicians

Planning Activity	Components
HVA	1. Hospital HVA process ● What are the most likely disaster scenarios identified by our hospital's HVA? ● Is the hospital disaster team aware of the critical care implications of those scenarios? 2. Critical care interface ● Are their critical care vulnerabilities not addressed in the hospital HVA? ● How are these vulnerabilities being addressed?
Surge plan	1. Space ● What is our baseline critical care capacity and what is our target surge capacity? ● What space is best suited to accommodate surge critical care patients and what impact will use of that space have on continuity of hospital operations? 2. Equipment ● What are our minimum equipment requirements for delivering essential critical care? ● What purchases/adaptations of available equipment must be made in the immediate future? ● What education is needed to familiarize staff with our disaster response equipment? 3. Staff ● What are the appropriate disaster staff-to-patient ratios for all essential provider types? ● Where/how will we obtain additional providers to supplement our staff? Does our staffing plan address the possibility of staff absenteeism? ● Do we have just-in-time training plans to prepare our staff to provide in disaster situations?
Allocation	1. Framework ● Do we have a written framework that has been reviewed/approved by relevant stakeholders? 2. Triage team ● How will our triage team be structured? Which specific staff will fill each triage team role? ● Has our triage team received appropriate training in the implementation of the framework? 3. Documentation and review process ● Do we have a clear plan for documentation of all allocation decisions? ● How will we review allocation decisions and ensure fair framework implementation?
Communication	1. Redundant communication ● What modes of communication are in place for communication within our healthcare facility? ● Are staff trained to use multiple communication modes and alternate procedures during outages? 2. Command center updates ● What are the main/alternate ways of communicating between the intensive care unit/hospital command center? ● What information must be communicated to the command center during an event? How often? 3. Data collection ● How will we collect epidemiologic and other relevant clinical data related to disaster victims? ● How will we communicate this information to central authorities, (e.g., the Centers for Disease Control and Prevention)?
Evacuation	1. Internal evacuation ● What scenarios may require internal evacuation? ● What criteria will we use to determine whether to evacuate our unit or shelter in place? ● To what space within our institution will we evacuate our unit? 2. External evacuation ● What criteria will determine which patients are transferred and which must shelter in place? ● How critical patient information be conveyed to transferring caregivers and receiving facilities? ● What is the plan for moving patients/equipment back to our intensive care unit once the crisis has resolved?
Drills	1. What internal drills have we completed in the last year? Have we incorporated lessons learned? 2. What is our plan for maintaining a baseline level of readiness by engaging in drills? 3. What external drills have we participated in? Are additional interfacility drills needed?

HVA, hazard vulnerability analysis.

training and just-in-time training to guide their use.

Delivery of mass ventilatory support is dependent on more than mechanical ventilators. Ensuring availability of sufficient amounts of medical-grade oxygen and adequate medical gas infrastructure is also essential. Oxygen systems include bulk liquid supplies, compressed gas cylinders, and oxygen concentrators. Both liquid and compressed gas cylinders can provide gas at 50 psig or at low flows (21). Bulk liquid is the main source of oxygen for hospitals and is the best option for supporting mass mechanical ventilation. Compressed gas cylinders can meet short-term oxygen needs. However, given cost and storage constraints, most hospitals maintain only enough cylinders to cover short-term disruptions of the bulk liquid system. Oxygen concentrators, most of which produce only low-flow oxygen using an electric compressor (22), may be useful for nonventilated patients who require supplemental oxygen and for ventilators driven by a compressor, turbine, or piston if they are already part of a given hospital's inventory.

Oxygen-conserving strategies may be necessary. Several recent studies have shown that a closed-loop controller that adjusts FIO_2 to maintain SpO_2 between 92% and 96% can reduce oxygen use compared with clinician FIO_2 adjustment in trauma patients (23–25). This device, however, is not yet Food and Drug Administration-approved, and its effectiveness in managing patients with medical causes of acute lung injury remains unclear. Ancillary equipment, including airway supplies, ventilator circuits, pulse ox probes, humidification devices, and suction equipment, must also be considered. The Mass Critical Care Task Force project, Definitive Care for the Critically Ill

During a Disaster, has provided comprehensive equipment guidance (6).

Staff. Provision of mass critical care will dramatically increase the need for a variety of specially trained critical care practitioners. Shortages of critical care trained nurses, respiratory care practitioners, pharmacists, and physicians exist even in the absence of a mass casualty event (26–33). Many of these shortages have persisted or progressed over years and are unlikely to be resolved in the near future. Given this challenge, careful development of surge staffing plans is critical. One potential source of critical care-capable staff may be departments of anesthesiology, especially if the response includes limiting the number of nonurgent surgical cases to be performed. Redirecting staff responsibilities in this manner and establishing memoranda of understanding to share staff and credential clinicians across facilities can help if some local hospitals are impacted more than others. Alternative strategies must be used, however, if a facility is geographically isolated or if many hospitals are simultaneously overwhelmed.

"Tiered staffing," as initially recommended by the Working Group on Emergency Mass Critical Care (9) and supported by the Mass Critical Care Task Force and others (6, 34), would increase the ability of critical care practitioners to oversee the care of vastly increased numbers of patients. This model calls for noncritical care-trained personnel to work collaboratively with critical care professionals to provide patient care. An example of training for such a strategy is Project Xtreme. The Agency for Healthcare Research and Quality in collaboration with the Department of Health and Human Service's Office of Preparedness and Emergency Operations supported development of this just-in-time training program for nonrespiratory care professionals to assist in caring for surges of ventilated patients (35).

Finally, as critical care units consider space, equipment, and staffing disaster plans, adult ICUs should give special consideration to the potential need to care for critically ill children. Pediatric ICU beds makeup <10% of all U.S. nonfederal critical care beds (13). Furthermore, the geographic distribution of pediatric ICUs is significantly more limited than that of adult ICUs (36), suggesting that significant surges in pediatric critical illness may necessitate use of beds in adult units. Adult ICU surge plans should define the size and age of pediatric patients that they are safely able to care for and should include contingency plans for those children who fall outside that range.

Allocation

During disasters in which the need for ventilators or other critical care resources dramatically exceeds demand, all feasible methods must be used to increase capacity, including interhospital transfers and use of alternate equipment. In addition, all nonurgent procedures and treatments that may impact the facilities' overall critical care capability must be delayed, as appropriate. If, however, demand exceeds all efforts to maximize surge capability, it is incumbent on hospitals to have established plans for the fair allocation of available resources.

Of all aspects of disaster planning, the development of a framework for the allocation of scarce critical care resources in a given community is perhaps the most sensitive and challenging. Several groups have published recommendations for allocating ventilators and other life support measures during a public health emergency (7, 37–40). The guidelines differ in which ethical criteria will be determinative, whether some patients should be categorically denied access to life support (exclusion criteria), and whether it is ethically permissible to withdraw a resource from one patient to give it to another who is more likely to benefit from it. Careful consideration of these questions in advance of a disaster is essential, because the necessary deliberations will not be feasible during a crisis.

Allocation of resources in situations of absolute scarcity necessitates a shift from caregivers focus on the needs of an individual patient to decisions based on what course of action may provide the highest survivability for the greatest number. Thus, public engagement is essential to both build public trust in such a difficult process and develop a framework that reflects community values. Although there are limited data on the best means to effectively engage the community on these potentially controversial ethical questions, guidance was recently published by at least two jurisdictions (41, 42).

Evacuation

An even greater challenge than that of addressing large surges in critical care demand is that of mobilizing critically ill persons from one care space to another to remove them from harm's way. Although as many as 20 hospital evacuations occurred annually in the United States during the 1990s (43), rigorous science and guidance on evacuation planning, like other areas of disaster response, is lacking (44, 45). Published accounts of the experience after the 1994 Northridge, CA, earthquakes seem to suggest that large hospital populations can be evacuated efficiently and safely with appropriate planning (46, 47). It may be argued, however, that the potential complexity of evacuations has increased rather decreased since that time, particularly with the advent of the electronic medical record. Planners should not underestimate the risk to patients engendered not only by the physical transfer, but also by information gaps resulting in patient care errors.

An ICU evacuation plan should address two major sets of questions, one surrounding the event necessitating evacuation and the other related to the patient. Given the diversity of events that may require evacuation, an HVA should guide prioritization of events to be included in evacuation plans. Planners should consider the nature of the threat along several lines: 1) is the threat a one-time event (use outage) or an ongoing hazard (earthquake with aftershocks or uncontained shooter); 2) will the response require instantaneous action (an "uncontrolled" event with immediate threat to life) or will some time be available to plan the evacuation (a "controlled" event); and 3) does the event necessitate evacuation of a single unit or the entire facility (44)?

Planners must also consider mechanisms for assessing relevant patient factors impacting evacuation safety. There must be a means to assess 1) the stability of the patient for a broad range of types of movement (manual transport down stairs, rotor wing or fixed-wing aeromedical transport); 2) the resources required (equipment and personnel); 3) the risks associated with continuing care in the at-risk location, "sheltering in place"; and 4) the best means to systematically communicate essential clinical data about the patient being evacuated to both transporting and receiving caregivers. Like with other decisions in disaster response, evacuation will require careful cost–benefit analysis incorporating all of these considerations.

Communication and Data Collection

Although communication is certainly important in routine patient care, having well-developed means for communication on multiple levels is the sine qua non of effective disaster response. ICU disaster planning should address several aspects of communication: 1) intrainstitutional situational awareness and use of incident command structure (ICS); 2) command center updates; and 3) collection and dissemination of data and real-time learning. Small institutions with one or few ICUs may have limited challenges with effective communication among their units regarding available beds, staffing levels, and additional stressors that may inhibit effective care delivery. However, larger institutions with multiple ICUs must plan to share information regarding patient load and resources across units. This is particularly true in the early stages of a response, either before an official disaster has been declared or when a slowly developing crisis such as a pandemic, is just beginning to emerge. Effective communication between departments/units can allow identification of "early warning signs" to inform developing disaster response decisions.

Once a disaster has been declared, prepared institutions will have established ICS to facilitate both communication and command and control. ICS, a standardized, all-hazards incident management structure, is used to facilitate coordinated response across federal, state, local, and institutional levels, as needed. Critical care planners should be familiar with this nationally recognized disaster response organizational structure and its use within their institution. Whenever possible, those responsible for ICU disaster response should obtain relevant ICS training (48).

ICS can facilitate communication across hospital units, and ICUs should be comfortable using its framework to communicate critical information to their hospital command center during a response. Use of redundant technology systems within this framework is essential. Hospital pager system outages, overloaded telephone lines, and power failures are common to disasters of all types. Response agencies have recommended that disaster plans include multiple methods of communication for essential information. ICUs and ICS command centers should have clearly outlined plan for what information needs to be communicated, in what format, and how often.

Finally, disasters caused by novel agents necessitate rapid learning. The severe acute respiratory syndrome outbreak and 2009 pH1N1 both demonstrated that real-time learning is at once necessary and difficult. Information on outcomes associated with ribavirin and steroid treatment for severe acute respiratory syndrome could inform management strategies only if collected and disseminated rapidly. The same was true both for alternate therapies for pH1N1 such as parenteral antivirals and for pH1N1 epidemiologic information needed to guide risk stratification. Development of mechanisms for both coordinated data collection and rapid review of institutional review board protocols for unproven therapies should be considered by all ICU disaster planners.

In summary, critical care disaster planners have a complex and challenging task. Experienced planners will agree that no disaster response is perfect. A well thought-out plan including specific local guidance directing 1) surge care plans; 2) allocation of critical care resources under conditions of absolute scarcity; 3) evacuation of at-risk facilities; and 4) effective internal communications and real-time data collection will enable the prepared ICU to effectively expand its capability in times of major crisis.

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